

CHAPTER 1 – BACKGROUND

INTRODUCTION

During the second half of the 1990s, coal bed methane (CBM) production increased dramatically nationwide to represent a significant new source of natural gas to meet ever-growing energy demands. In Montana, oil & gas development has been growing since the first oil wells were drilled in the early 20th century. Today, Montana's oil and gas industry exceeds 300 million dollars per year and is a significant aspect of the state's economic livelihood. Recent oil and gas exploration and development in the state has included a focus on CBM exploration and development. There are currently more than 200 commercially producing CBM wells in the state of Montana, all of which are located in the Powder River Basin near the town of Decker, Montana. CBM development in the Montana portion of the Powder River Basin (PRB) is in part a result of successful development in the Wyoming portion of the basin where CBM activity started as early as 1993 (Flores et al, 2001).

A primary intent of the Montana CBM Environmental Impact Statement (EIS)¹ is to provide an overall projection of impacts associated with CBM development for the planning areas and to address issues raised as part of the public scoping process. Of primary consideration for the EIS are water resources. Due to the extraction methods required for CBM production, impacts can potentially result from CBM development. The purpose of this Water Resources Technical Report is to serve as one of many supporting documents for the subject EIS.

PUBLIC SCOPING ISSUES

During the scoping process for the Montana CBM EIS, the public was provided with the opportunity to review and comment on resource issues identified as important by the Bureau of Land Management (BLM) and the State of Montana. The public was also provided an opportunity to identify new issues and comment on the Draft Planning Criteria. During the public comment period, more than 2,100 comments in more than 300 separate responses were received (ALL, March 2001). Of those comments, more than 850 related to water resource issues. Water issues raised through the public scoping process are summarized below:

Groundwater Quality and Quantity

This category of comments pertains to the effects of CBM development on groundwater quality and quantity. A total of 140 comments were received in this category. A number of comments suggested that CBM pumping would degrade groundwater quality. Other comments made note of possible cumulative effects resulting from CBM pumping, and requested that cumulative groundwater impacts be included in the study. Several comments expressed concern that CBM pumping would deplete the quantity of groundwater. Additionally, concerns were expressed that groundwater aquifers would be contaminated from either open boreholes (artificial penetrations) or saltwater pumped from the ground. Several comments were also received that called for 3-D modeling to be performed as a means of predicting impacts to groundwater.

Surface Water Quality and Availability

A total of 198 comments were received that dealt with surface water quality and availability. Comments concerning the impact to surface water from CBM discharge were the most prevalent (129 comments). Other comments questioned the cumulative/long-term effect as a result of discharge of CBM water (54 comments). Several respondents expressed concern about CBM discharge water coming from Wyoming and the resultant impacts on Montana surface waters. Other comments mentioned in this section include interest in decreased surface water availability, and concerns about the wasting of groundwater as a resource.

Wastewater Disposal and Discharge

This category of comments pertains to the disposal and discharge of water from CBM production. A total of 97 comments were received. Comments in this section included siltation of rivers from increased flows, treatment of discharged water, landowner input into discharge on his/her land, and questions related to the injection of discharged water. The two most prevalent comments concerned: 1) The re-injection of wastewater into the same

¹ The BLM and State of Montana are currently preparing an Environmental Impact Statement for CBM development and development of conventional oil & gas. However, the development of CBM is a primary factor of this document.

formation rather than surface disposal (42 comments); and 2) The suitability of the discharged water for livestock and agricultural use.

Water Conservation

Water conservation issues were the most common comment received during the scoping process. A total of 260 comments were received that dealt with water conservation. The water conservation topics covered aquifer drawdown and recharge, water replacement cost, permitting questions, and the wasting of water resources. The two most common comments were: 1) Water recovery wells will go dry due to a lowered water table as a result of CBM development (119 comments); and 2) Aquifer recharge rates will be affected due to CBM development (90 comments). On the evidence of the comments, there was a particular interest concerning the fate of private water wells under the influence of CBM development. Based on review of the scoping comments, it is evident that public groundwater concerns exist in many areas of the state, but are most acute in the Powder River Basin (PRB).

Water Rights

A total of 67 comments were received that discussed the issue of water rights. Most of the comments were questions on the CBM use of groundwater without obtaining the rights to produce the water. Several comments reviewed suggested the need for the Environmental Impact Statement (EIS) to ensure that water rights and/or groundwater resources would be protected.

Groundwater Resource Assessment

There were 78 comments that recommended the preparation of a groundwater resource assessment. Over half of the comments (55 comments) stressed the need to gather baseline data on all groundwater resources prior to development of CBM. The second most prevalent comment (14 comments) was a request to prepare a three-dimensional (3-D) map of all the aquifers in the project area. Other comments included the need for a regional water plan and development of a groundwater resources database.

STUDY AREA

The planning area for the EIS is defined as the area where oil and gas decisions will be made by the BLM and the State of Montana. The BLM's planning area is the oil and gas estate administered by the BLM in the Powder River and Billings Resource Management Planning (RMP) areas. The State of Montana's planning area is statewide, with emphasis on the state-administered oil and gas within the BLM planning area and in Blaine, Park and Gallatin counties. The planning area excludes those lands administered by other agencies (for example, Forest Service and Tribal Councils).

For ease of reference, the Billings and Powder River RMP areas, and Blaine, Park, and Gallatin counties, are referred to in the document as the BLM and State "CBM emphasis area." This is the 16-county area within the BLM and state planning area where CBM development interest has been identified.

The Powder River RMP area encompasses the southeastern corner of Montana, including Powder River, Carter, and Treasure counties, and portions of Big Horn, Custer, and Rosebud counties. The Powder River RMP area comprises approximately 1,080,675 acres of federally managed surface and 4,103,700 acres of federal mineral estate.

The Billings RMP area comprises the south-central portion of Montana consisting of Carbon, Golden Valley, Musselshell, Stillwater, Sweet Grass, Wheatland, and Yellowstone counties and the remaining portion of Big Horn County. The Billings RMP area comprises approximately 425,336 acres of federally managed surface and 906,084 acres of federal mineral estate.

Adjacent to the planning areas, other major land holdings include the Crow, Northern Cheyenne and Fort Belknap Indian Reservations, the Custer National Forest, portions of Yellowstone National Park, the Big Horn Canyon National Recreational Area, the Burlington Northern and Santa Fe Railroad, and the Fort Keogh Agricultural Experiment Station. The total surface area of the CBM emphasis area (all owners) exceeds 25 million acres.

Although a CBM emphasis area has been identified for purposes of the EIS and Resource Management Plan (RMP) Amendment, the primary area of concern identified during the public scoping process is the PRB of Montana. The Montana PRB is also the area where CBM development is expected to be most intense. For the purposes of this Technical Report, analyses will primarily focus on the Montana portion of the PRB. Exhibit 1 is a map showing the

entire state of Montana, the CBM emphasis area, and other points of interest for reference throughout the remainder of this report.

REASONABLE FORESEEABLE DEVELOPMENT SCENARIO

To facilitate planning and the determination of potential environmental consequences, the BLM prepared a Reasonable Foreseeable Development (RFD) scenario. The RFD predicts oil and gas development in five areas: the Powder River RMP area, the Billings RMP area, and in Blaine, Gallatin, and Park counties of Montana. The RFD projects drilling of both conventional and CBM wells, numbers of pipelines, and compressors needed for production of CBM wells.

For CBM exploration and development, the areal extent of certain coals and the rank of coals in the study areas were considered. Areas of sub-bituminous to bituminous coals were considered as most likely to be explored and developed in Montana, although exploration and development has occurred mainly in sub-bituminous coal in the Wyoming portion of the Powder River Basin. The USGS produced a map showing the areas of coal, by rank, for the United States. This information indicates sub-bituminous and bituminous coals in many parts of the study area. Powder River, Rosebud, Custer, and Big Horn counties contain the northern part of the Basin, which extends north from Wyoming. Blaine and Musselshell counties have mostly sub-bituminous coal. Carbon County has an extension of the Big Horn Basin coal, which is ranked as bituminous coal. Gallatin and Park counties have scattered areas of bituminous to sub-bituminous coals. The projection of methane gas to be produced from coal beds in Montana range from a low of 1 TCF (Fred Crockett-PRB est -RMG, Casper) to a high of 17.7 TCF (estimated based on figures from Nelson, 2000). This and other information for Montana was used to predict where CBM exploration is most likely to occur in the emphasis area. The RFD predicts the number of CBM wells that would be drilled and completed during the next 10 to 20 years. For CBM, potential development in the RFD was estimated to be as much as approximately 26,000 wells in the next 20 years.

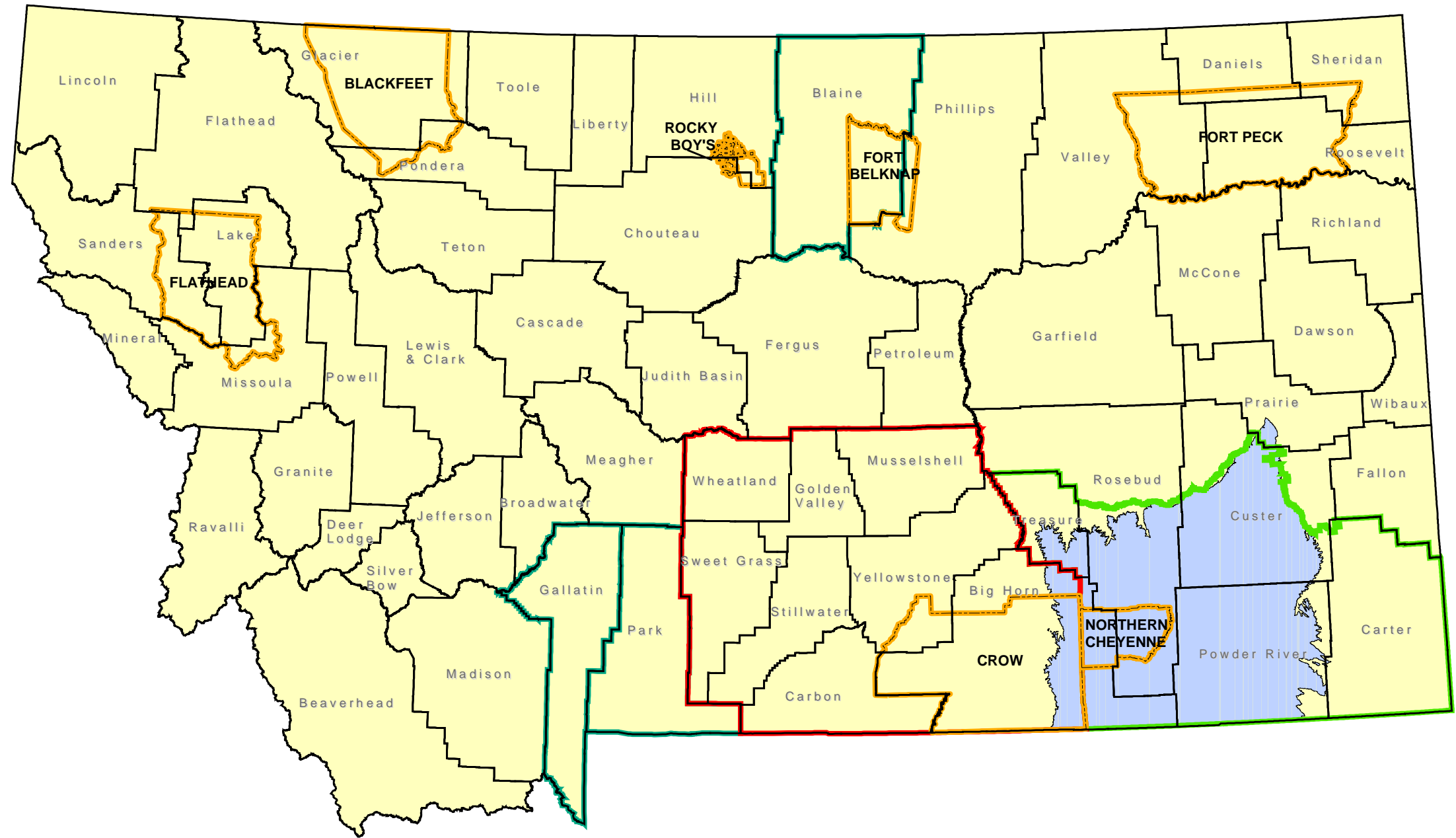
Historical drilling activity and oil and gas price projections were used to project conventional oil and gas development for the emphasis area (above). The RFD scenario describes a somewhat different level of activity than the scenario found in the BLM *Final Oil and Gas RMP/EIS Amendment* issued in 1992. This is primarily because of the use of a different span for historical drilling activity. The 1992 amendment used the span from 1973 to 1988 in forecasting future activity. The document used a total period of 80 years in forecasting future development. This led to a slight difference in the level of drilling activity forecast. Approximately 200 to 800 wells would be drilled in the Powder River RMP area. Approximately 250 to 975 wells would be drilled in the Billings RMP area. A total of 450 to 1,775 wells would be drilled in the next 20 years.

Exhibit 2 shows the total RFD for the CBM emphasis area, which includes the Montana portion of the PRB. Also shown on this exhibit are Native American Reservations, National Forests, National Parks, and National Recreation Areas. Review of this exhibit shows potential CBM development throughout the majority of the Montana PRB. Estimates are based on full-field development by county and shaded areas represent occurrences of sub-bituminous coals within the counties where development is likely to take place.

Analysis of the RFD with respect to the Montana portion of the PRB suggests that approximately 4,095,000 acres of the total 5,984,000 acres that make up the PRB are expected to have CBM development. The total RFD for this area (including federal, state, and private mineral ownership) amounts to approximately 24,875 total CBM wells. Exhibit 3 illustrates the maximum potential well development as described in the RFD by watershed, shaded for coal occurrences within the basin. This exhibit shows how the predicted CBM development from the RFD intersects watersheds in the PRB of Montana. The development scenario presented in this exhibit represents total drilled wells. It is expected that about 10 percent of these wells will be dry holes.

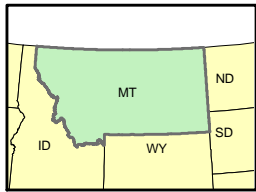
Exhibit 4 indicates the surface area of each watershed within the PRB overlying the known coal occurrences and the predicted number of maximum wells per watershed. This exhibit shows that the potential total area within each watershed that may be impacted by CBM development ranges from 24,000 acres (Mizpah watershed) to approximately 1.3 million acres (lower Tongue watershed). Similarly, CBM development ranges from high concentrations of approximately 5,809 and 5,397 in the upper Tongue and Rosebud watersheds, respectively to only 224 CBM wells in the Mizpah watershed. Consider the total RFD for the state, this exhibit shows that the vast majority of CBM development is expected to occur in the Montana portion of the PRB.

**Exhibit 1:
EIS Planning
Area and CBM
Emphasis Area**



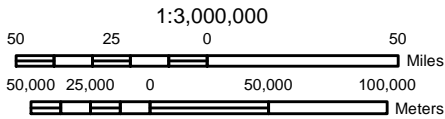
Legend

- Billings RMP Area
- Powder River RMP Area
- Special Consideration Counties
- Native American Reservations
- Powder River Geologic Basin



Location Map

Date Prepared: May 6, 2001
Prepared by: J. Patton
Project Mgr.: D. Arthur



DATA SOURCES:
Counties: 1:100,000 scale, counties, Montana State Library/NRIS, Helena, Montana.
Reservations: 1:100,000 scale, counties, Montana State Library/NRIS, Helena, Montana.
BLM RMP Areas: 1:100,000 scale, BLM State Office, Billings, Montana.
Powder River Geologic Basin: 1:250,000 scale, USGS Professional Paper 1625a.

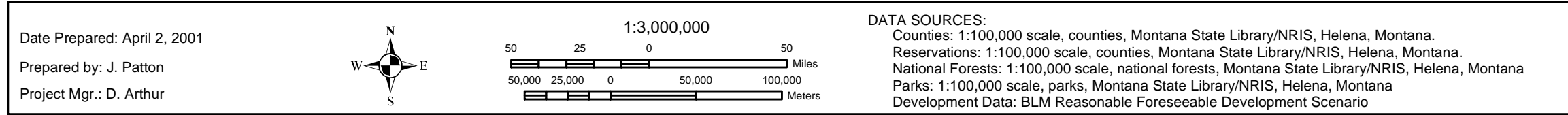
Legend

-  Native American Reservations
-  Special Consideration Counties
-  Powder River RMP Area
-  National Forest
-  Billings RMP Area
-  National Recreation Area
-  Yellowstone National Park

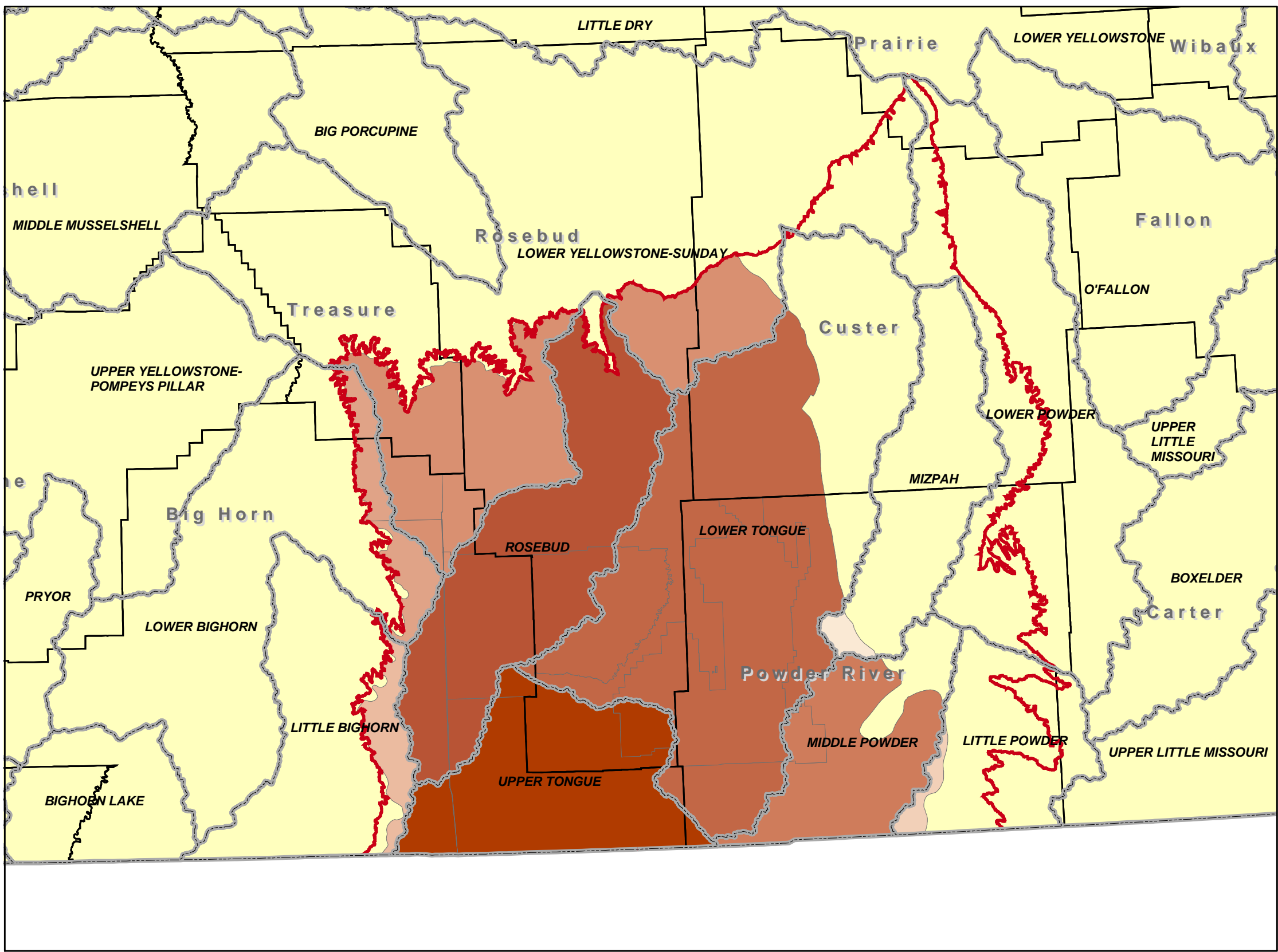
Potential # of Wells

-  Minimal
-  1 - 150
-  151 - 400
-  401 - 700
-  701 - 4000
-  4001 - 7000

A map of Montana (MT) in green, surrounded by yellow states: Idaho (ID) to the west, Wyoming (WY) to the south, North Dakota (ND) to the northeast, and South Dakota (SD) to the east. The map is titled "Location Map" at the bottom.



**Exhibit 3:
Predicted Number
of CBM Wells by
Watershed in the
Montana Portion of
the Powder River
Geologic Basin**



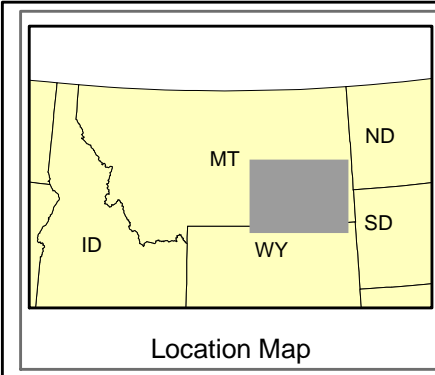
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Watershed Boundaries
Powder River Geologic Basin Boundary
Special Consideration Counties

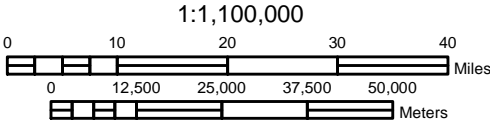
Predicted # of CBM Wells Per Watershed

225
280
1050
1200
2570
3170
5180
5400
5810

This figure represents the predicted number of Coal Bed Methane Wells in the Montana Portion of the Powder River Basin by watershed based on the Reasonable Foreseeable Development Scenario for full-field development.



Date Prepared: April 2, 2001
Prepared by: J. Patton
Project Mgr.: D. Arthur



DATA SOURCES:
Counties: 1:100,000 scale, counties, Montana State Library/NRIS, Helena, Montana.
Reservations: 1:100,000 scale, counties, Montana State Library/NRIS, Helena, Montana.
National Forests: 1:100,000 scale, national forests, Montana State Library/NRIS, Helena, Montana.
Parks: 1:100,000 scale, parks, Montana State Library/NRIS, Helena, Montana.
Development Data: BLM Reasonable Foreseeable Development Scenario
Coal Occurrence: Tully, 1996.

NOTE: To be used as a reference graphic only. Some data represented are at scales greater than it's source.

EXHIBIT 4 - WATERSHED ACREAGE AND MAXIMUM POTENTIAL CBM WELLS IN THE PRB

This table indicates the surface area of each watershed within the PRB overlying known coal occurrences and the predicted number of maximum potential wells per watershed.

WATERSHED	SURFACE ACREAGE OF IMPACTED WATERSHED	POTENTIAL WELLS DRILLED
Little Bighorn	87,000	1,050
Little Powder	29,500	278
Lower Bighorn	121,500	1,200
Lower Tongue	1,374,000	5,183
Lower Yellowstone-Sunday	687,500	2,568
Middle Powder	368,500	3,167
Mizpah	24,000	224
Rosebud	814,000	5,397
Upper Tongue	589,000	5,806
Total	4,095,000	24,875

APPROACH AND METHODOLOGY

Hydrological resources in the PRB are vitally important to residents of this semiarid country. In a region that receives 16 inches or less of precipitation each year (NOAA 2001), residents want to understand the possible impacts of produced water derived from CBM. Each productive CBM well produces water from underground coal seams in quantities that can be quite large over the life of an individual well. Assuming an average life of perhaps 20 years, a single CBM well could produce as much as 105 million gallons of water². Considering a possible development scenario of approximately 26,000 CBM wells throughout the CBM emphasis area, the total volume of water produced from CBM wells in Montana could exceed 3 trillion gallons of groundwater³.

Because of the volume of water being considered, its origin, and quality, several issues that do not commonly cause significant concern with respect to conventional oil and gas development may pose potential significant threats with respect to CBM development. To better understand these issues, this technical report uses an approach that emphasizes known information so clarified understandings of the existing environment and impacts from CBM development can be achieved. Specific issues identified for review in the technical report are listed below with brief descriptions of each issue:

✍✍ **Hydrologic Setting and Framework:** Significant study has been performed on the hydrologic settings and framework in the CBM emphasis area and the PRB. To facilitate the assessment of environmental consequences of CBM development, a thorough understanding of this framework is instrumental. Discussion of the hydrologic framework will include some statewide discussion, with emphasis on the PRB.

✍✍ **Hydrology Regime:** The extent of the groundwater resource will be included in a water balance discussion of present and future usage.

✍✍ **Coal Seam Reservoir Parameters and Regional Variations:** Throughout the CBM emphasis area and the PRB, underground coal seams vary substantially. Although fully defining the reservoir parameters and all regional variations are not possible or practical, the report presents general information regarding the characterization and heterogeneity of potential CBM producing coal seams that are likely to be primary targets for exploration and production activities.

² Average long-term production rates for CBM wells could be as much as 10 gallons per minute over the life of a typical well. Therefore, the total water volume for 20 years of active production would be approximately 105 million gallons (*Calculation: 12 gallons per minute x 60 minutes per hour x 24 hours per day x 365 days per year x 20 years*). However, based on declining water production rates, the anticipated averaged production rate for a CBM well is 2.5 gpm over a 20 year production period.

³ Total produced water volumes for full-field development, including approximately 24,000 production wells, would amount to more than 3 trillion total gallons of water (*Calculation: 126 million gallons per well x 24,000 potential wells*).

- ✂ **Faulting and Fracturing Relative to CBM Development:** The entire CBM emphasis area is a complex geologic framework with areas that have prolific faulting and fracturing. The presence of faults and fractures in the CBM emphasis area (including the Powder River Basin) has raised concern regarding the potential influence these faults and fractures may have. This document discusses faults and fractures as barriers and storage features.
- ✂ **Artificial Penetrations:** Considering the relatively shallow depths to potentially productive coals in some parts of the CBM emphasis area, concerns regarding artificial penetrations have been raised through the public scoping process. Therefore, a discussion relative to artificial penetrations has been included in the Technical Report.
- ✂ **Groundwater and Surface Water Interaction:** Understanding hydrologic systems can provide insight toward evaluating potential impacts of a proposed action. Under CBM development, both groundwater and surface water impacts are discussed.
- ✂ **Groundwater Production and Usage by Aquifer and by Area:** To better understand groundwater issues relative to CBM development, a basic understanding of groundwater production and usage is necessary. Therefore, available information concerning production and usage is presented.
- ✂ **Water Quality Characterization and Impacts:** Possible water quality impacts from CBM development, including geographic distribution of potential impacts, are largely unknown. A general water quality characterization of both groundwater and surface water can be accomplished by analysis and review of existing data. Furthermore, insight into previous and ongoing analyses in this area is believed to be necessary for ultimate determination of environmental consequences.

In addressing the above technical issues, data will be acquired from a variety of sources, including the Montana Bureau of Mines and Geology (MBMG), Montana Department of Environmental Quality (MDEQ), Montana Board of Oil & Gas Conservation (MBOGC), United States Geological Survey (USGS), and the BLM. Other information and data sources will be used as determined necessary.

GROUNDWATER MODELING

Groundwater modeling is not being conducted as part of the technical analysis of this document. Results from various groundwater models performed as part of separate CBM studies have been considered. Environmental impacts from water production as a part of CBM activity can be predicted by modeling current conditions and expected development. Mathematical modeling calculates changes in hydraulic head because of withdrawal of water and measured reservoir parameters. Mathematical models require a certain level of knowledge of local conditions, including reservoir pressures, reservoir parameters such as porosity and permeability, and potential producing rates. Modeling can involve simple two-dimensional (2-D) calculations to quantify the potential radius of drawdown influence. If localized knowledge is sufficient, a 3-D model can be constructed that honors directional changes in reservoir parameters and complex interferences of multiple producing wells. Groundwater models that have been performed with respect to CBM production considered in this document are as follows:

- ?? The Buffalo, Wyoming, Field Office of the BLM contracted with a hydrology firm to produce a multi-layer 3-D model of the Wyoming portion of the PRB (BLM, 1999a). This model (VMODFLOW v.2.61) consisted of eight isotropic layers including coal and sand aquifers and various aquacludes. The modeling was intended to predict spatial and depth distributions of water level drawdown within several aquifers and to predict cross-flow between aquifers.
- ?? The Durango, Colorado, District Office of the BLM (BLM, 2000a) contracted a single-layer (VMODFLOW v. 2.8.2) model of the New Mexico and Colorado portions of the San Juan Basin (SJB), an area of intense CBM development. The modeling was designed to predict water level drawdown within the generalized coal aquifer.
- ?? Small-scale, two-dimensional models have been performed in the PRB (Williams, B. 2001; Pennaco 2000; Peacock et al, 1997). These models are single-layer expressions of fluid-flow equations assuming isotropy. The models are intended to predict water level drawdown in a single aquifer in terms of radius from extraction points or the center of a proposed well field.

Predictive modeling of groundwater in the Montana portion of the PRB is hampered by three data deficiencies, hydraulic parameters of the coal aquifers, anisotropy (directionality) of reservoir parameters, and geographic distribution of CBM development areas. Only one small area has been developed for CBM in the PRB emphasis

area—the CX Ranch represents an area of approximately 11 square miles. The CX Ranch contains nearly 200 producing wells that have yielded reservoir data such as porosity, permeability, hydraulic conductivity, and storage coefficients in the subsurface. The subsurface analyses from full-hole cores gives a good approximation of these important reservoir down-hole properties. On the other hand, analyses from outcropping surface coals (Davis 1984 and Montana Department of State Lands (MDSL) 1982) produce data that may or may not be close approximations of subsurface measurements (BLM 1999a). Exposure at the surface dries out the coal, accentuates cleat (natural fracturing) and apparent porosity, and changes the texture of shaley interbeds; this may significantly alter reservoir parameters (BLM 1999a). Additionally, multi-well pumping tests in the emphasis area are almost non-existent; multi-well testing is the best way to evaluate reservoir conditions beyond the dimensions of the single bore-hole (BLM 1999a). The lack of high quality reservoir parameters from subsurface samples and multi-well pumping is a definite hindrance to 3-D modeling.

The directionality of reservoir parameters, such as permeability and hydraulic conductivity, has not been examined throughout most of the Montana portion of the PRB (Davis 1984). Permeability and hydraulic conductivity are dependent on matrix porosity and fracture development. Fracturing may be due to regional scale tectonics such as those associated with the northeast southwest faulting around the CX Ranch area (Bergantino 1980), or may be due to flexing over structural noses and four-way closures in the area. In any given area, fracturing can be due to several causes and be extremely variable in direction and density. The effect of directionality may exceed 250 percent (Davis 1984).

Three-dimensional modeling can predict possible combined effects from closely spaced CBM developments. In the PRB, however, it is unknown where these future CBM fields might be located, or how many might be in place within the next 10 or 20 years. In particular, it is unknown whether the upper Tongue River Member coals will be the only economic CBM reservoirs or whether deeper coals may also be economic. Future economics will also determine the spacing and number of CBM fields throughout the Montana PRB.

Due to these complexities, the BLM and State made the determination to ask the MBMG to move forward with two (2) separate groundwater-modeling projects specifically tailored to the needs of the EIS. These models will include a two-dimensional single-layer model of the PRB to determine drawdown effects of potential CBM development and a 3-dimensional model of a hypothetical CBM project in the area of Hanging Woman Creek. Results of these models will serve a similar purpose as this technical report and will be used in support of the Montana CBM EIS.